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BRIEF PRESENTATION OF THE CHARACTERISTICS, CONTAMINANTS, PROCESSING, AND USES OF BEESWAX

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Composition of Beeswax

Beeswax is the substance secreted by worker bees for use in constructing combs. These combs serve numerous purposes in the bee economy and are often used for a long time as first built, or the wax may be reworked into new combs. Virgin scale wax, as secreted by the bees, is of uniform composition, being a complicated mixture of esters, free fatty acids, and small quantities of sterols, and its production has been found (3, 4)[2] to follow the consumption of sugars only. The crude beeswax that appears on the market, however, varies greatly in its characteristics. Such wax contains numerous impurities, including propolis, wax-soluble colored substances from pollens, metallic salts of organic acids, and suspended solids, such as insects, straw, and dust. Variations in the nature of the impurities and in the proportion in which they are present give rise to waxes having an almost infinite variety of chemical and physical characteristics, which affect their suitability for commercial uses. Some of these impurities cause bleaching difficulties, some result in the clogging of candlewicks, and others affect the acidity, color, texture, or unsaturation of the wax. Since it is highly desirable that a more standardized product be available to compete with other standardized waxes, a study has been made of a number of crude beeswaxes in an attempt to find a basis for their classification.

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[1] This circular is based on the results of investigations made in cooperation with the University of California.

[2] See Literature Cited, page 11.

Chemical and Physical Properties of Beeswax

Certain chemical and physical properties of 60 samples of crude beeswax have been summarized in table 1, together with the properties of pure beeswax. The differences between the values for the crude and the pure waxes are evidently due to impurities.

Table 1.--Chemical and physical values of crude and pure beeswax

Property	Crude beeswax[1] Range	Crude beeswax[1] Average	Pure beeswax
Acid number	16.8 - 35.8	19.2	17.0
Iodine number (Hanus)	6.8 - 16.4	10.2	5.8
Saponification number	89.3 - 149.0	96.7	84.4
Ash content	0.005 - 0.037	0.019	Near 0
Melting point, °F	143.6 - 149.0	147.2	147.9±1
Solidifying point, °F	141.3 - 146.3	144.9	146.3±0.9
Density at 68° F	0.947 - 0.987	0.961	0.963
Refractive index at 176° F	1.4388 - 1.4527	1.4407	1.4402
Color	Pale yellowish white	Brown	White

[1] Based on 60 samples.

Propolis Contamination

Some of the most serious problems arising in the final consumption of beeswax are traceable to propolis contamination. To illustrate this point, the average acid number of the wax that we collected from scales is 17, whereas that for one sample of propolis is 125. Very little imagination is necessary to see what happens to this important chemical property of beeswax when it contains a high percentage of propolis. One of our samples from comb-honey scrapings contained 16 percent of propolis. The wide acidity variable found in our samples is apparently due to the propolis content. The most serious complaint of variable acidity has come from the cosmetic manufacturers, one of the largest single outlets in this country. A formula giving a satisfactory manufactured product with beeswax of a certain acid number gives a great deal of trouble when a beeswax of a different acidity is used. Propolis also ruins beeswax for candle making, because it chars on the wick with consequent guttering, spilling over, and flaring up.

Though propolis is objectionable when the wax is consigned to certain uses, it is apparently acceptable in mixtures for plant grafting, thread waxing, and waterproofing. Many crude waxes, when properly rendered, have a delightful aroma, no doubt from contact with propolis as well as from other substances from which essential oils are adsorbed.

The gums and pitches which constitute propolis are not secreted by the bee, but originate from numerous plant sources, especially species of

poplar in the West. They vary in color, odor, gumminess, and, undoubtedly, in chemical composition. The bees instinctively collect this gum for use in the hives, as for closing spaces too small to admit a bee and for plugging large openings. The sticky material that accumulates from scraping comb-honey sections is nearly all propolis, and should be destroyed. Several excellent articles on propolis have appeared (1, 2, 6, 8).

Coloration of Beeswax

Freshly secreted beeswax is white, but it readily adsorbs colors from various sources. Some pollens carry yellow substances, which are liberated to the beeswax in either solid or liquid state. A cell in a new bee comb, as well as the walls of the adjacent cells, becomes very yellow when melted in glass with fresh pollens collected from various plants. It was found that color was liberated from pollen much more slowly after the grains had become dry. The results from several tests with white wax and pollens appear in table 2.

Table 2.--Color imparted to liquid beeswax by pollen from various plants arranged in order of intensity of the resultant shades

Plant source of pollen	Natural color of pollen	Color imparted to white beeswax
Red maids (*Calandrinia caulescens*)	Orange yellow	Brilliant orange yellow
California poppy (*Eschscholtzia californica*)	Golden	Brilliant orange yellow
Sunflower (*Helianthus bolanderi*)	Golden	Bright orange yellow
Dandelion (*Taraxacum officinale*)	Bright yellow	Bright yellow
Spikeweed (*Hemizonia fitchii*)	Golden yellow	Bright yellow
Perennial sunflower (*Wyethia angustifolia*)	Bright yellow	Bright yellow
Deciduous fruits	Yellow to brown	Yellow
Gum plant (*Grindelia camporum*)	Golden yellow	Yellow
Black mustard (*Brassica nigra*)	Light yellow	Light yellow
Asparagus (*Asparagus officinalis*)	Orange	Pale yellowish orange
Star-thistle (*Centaurea solstitialis*)	Pale yellow	Slight yellow
Willow (*Salix* sp.)	Yellow	Very slight yellow
Broom (*Cytisus scoparius*)	Orange red	Trace of yellowish orange
Ladino clover (*Trifolium repens*)	Brown	Trace of yellow
Filaree (*Erodium cicutarium*)	Bright red	None
Unknown	Greasy yellow	None
Orchard morning glory (*Convolvulus arvensis*)	White	None
Alfalfa (*Medicago sativa*)	Yellowish brown	None
Algaroba (*Prosopis chilensis*)	Pale yellowish	None
Flax (*Linum usitatissimum*)	Greenish blue	None
Unknown	Blue	None
Unknown	Purple	None
Globe artichoke (*Cynara scolymus*)	Creamy white	None
Hollyhock (*Althaea rosea*)	White	None

When a wax-staining pollen is mounted in water and examined under a microscope, yellow oil-like droplets can be seen protruding from the pollen grains. These drops eventually break loose and float away in the water.

Propolis also causes a yellowish, orange, or brownish coloration when mixed with white beeswax. Wax discolored by propolis is very difficult to bleach, whereas color originating from the pollen ordinarily responds well to bleaching with sunlight.

Chemical activity between iron, water, and some constituents of crude beeswax is fairly rapid at the temperature of boiling water. The dark-brown substances that form produce a very dark wax. The high temperature was formerly supposed to be the cause of this dark color, but crude and white waxes held in water at 212° F. for 48 hours in containers of glass, platinum, stainless steel, aluminum, or nickel were not appreciably changed in appearance. It is significant that old dark combs yield a yellow wax when rendered in vessels made of any of these substances. Monel metal gave only slight discoloration. Some darkening of wax from iron takes place even in the hives at points of contact between iron and comb. Note the discoloration along the frame wire in figure 1.

Rendering of Crude Beeswax

Crude wax is usually rendered from the frames and from scrapings by melting over hot water or under solar heat. Since significant contamination may occur during this process, a brief discussion of these procedures is included.

Hot-water extraction process.--Beeswax from broken combs or cappings is usually melted out over boiling water. The container should be filled with boiling water to about one-fifth or one-fourth of its capacity, and the whole mass, after addition of the waxy materials, should not occupy more than three-fourths of the total space, especially when the operation is carried on over direct heat. Care should be taken to avoid boiling over, with consequent loss of wax and danger of fire. A common practice, worthy of retention, consists in soaking the combs in cold water for several hours before melting. In this way the silken cocoons and other foreign matter are filled and wetted with water so that when the mixture is heated the melted wax is not absorbed by them, and water-soluble materials, including honey, which promote granulation of the wax, are washed out.

For small quantities of material the melted wax and water can be separated from the other materials by squeezing the liquid through a wet cloth. Upon cooling, the wax solidifies into a cake on top of the water. This crude wax may be partially cleaned of fine dirt by scraping away the bottom of the cake.

Where a large quantity of comb is to be rendered, some type of press is essential to help separate the wax from the slumgum or impurities. A wax press employing hot water is perhaps as satisfactory as any available

on the market. High or low pressure steam is a good indirect source of heat for melting wax.

The water used in the melting process should be as nearly pure as possible. Some components of crude beeswax are acid, and certain alkaline impurities in the water cause finely divided insoluble solids to separate in the wax. Rain water is very satisfactory. Well water that contains sufficient chemicals, such as calcium, magnesium, and sodium salts, to make it hard or abnormally soft should be avoided. The addition of a small amount of acid to the water may occasionally be desirable. Vinegar, which is safe to handle, may be used for this purpose. The use of acids in wax-rendering equipment, however, greatly hastens the destruction of the zinc coating on galvanized iron.

Although several substances were used experimentally to coat containers to prevent the contamination of wax by iron during rendering, the tests yielded no encouragement. Substitution of stainless steel or, in some cases, aluminum for the cheaper metals now used in wax equipment would be genuine economy. Wood and glass also make excellent containers for the manipulation of liquid wax.

Solar extraction.--Crude wax from cappings can be rendered by exposing the material to the sun (fig. 2) in a solar extractor. Sun melting reduces the intensity of wax color and causes the removal of soluble contaminating substances through coagulation. Old combs are not so successfully handled by this method. Disease-infected materials should not, in any case, be placed in this type of melter because of the danger of spreading the infection. Destroy such materials by burning.

One large producer in the Sacramento Valley of California, in preparing cappings for solar extraction, lets the cuttings fall into hardware cloth boxes, which are supported over a long, shallow draining trough, thus allowing the cappings honey to run into the general stream from the extractor. As each box becomes filled, it is slid along the rack and replaced by an empty one. When the cappings are sufficiently drained of honey, each box is transferred to an individual solar extractor. A long, narrow extractor could be constructed to accommodate several of these boxes, thus increasing the efficiency of the process.

A small, shallow solar extractor, measuring 16 by 30 inches, will handle about 2 gallons of crude material at a filling, while a deep type, measuring 42 by 48 inches, will accommodate 16 gallons or more.

Considering the superiority of beeswax melted out by the sun over that rendered over water in the ordinary galvanized-iron equipment, more extensive use of solar extractors is unhesitatingly recommended. The heat energy for sun melting causes no financial drain and is available everywhere. The solar equipment on the market at present, however, falls somewhat short of perfection. Large extractors are possible and highly practical. The solar extractor should be built to retain heat throughout, and the bottoms of

most extractors as now constructed are particularly weak in this respect. Double glass construction has been found in experimental work to assure higher temperature and more rapid melting out.

Galvanized iron is a very satisfactory construction material for the solar extractor. Chemical activity between the wax and the zinc-coated iron is slight because of the absence of water, except for the small amount in the honey. On the other hand, for construction of a vat or press to be used in the hot-water rendering process this material is very objectionable.

Persons unfamiliar with wax rendering will find an excellent illustrated discussion of this process in Root's "ABC and XYZ of Bee Culture" (5). The "darkening by heat" is now known to refer to iron staining of wax, since this metal is the true cause of the phenomenon. Equipment for extracting wax can be purchased from several manufacturers of supplies. Whenever feasible, however, the practice of having beeswax rendered in commercial plants should be encouraged, because increased production of a wax with superior quality and color usually results.

Clarification of Crude Beeswax

After the coarse particles of material in the melted beeswax have been removed by straining through wet cloth, other suspended particles and cloudiness can be partially removed by boiling the wax for at least 10 minutes in dilute (5 percent) sulfuric acid. The particles coagulate and settle, and the clear liquid wax may be drawn off or the dirt scraped from the bottom of the cake after the wax solidifies. Protracted boiling does not injure the wax as long as no chemical reaction takes place between the wax and the container wall. Freedom from particles is highly important if the wax is to be used for candles, since foreign matter will quickly clog the wick in burning.

Generally speaking, a producer of crude beeswax may well avoid the use of dangerous acids. Concentrated sulfuric acid injures animal tissues, clothing, and certain metals, and should therefore be handled with caution during clarification. In mixing sulfuric acid solution, the acid should always be poured into cold water. After the water and acid mixture has reached boiling temperature, add the wax and let the boiling continue for at least 10 minutes.

Oxalic acid may be substituted for the sulfuric, but it is quite poisonous. Phosphoric acid is also sometimes recommended for clarifying beeswax, but the writers' tests with it did not give satisfaction, and it is expensive.

Excess acid can be removed by washing the molten wax with three times its volume of fresh hot water and stirring vigorously. Acid treatment, followed by thorough washing, changes the original acid number of the wax but slightly, as demonstrated by repeated tests and analyses. Beeswax appears to be slightly harder and more brittle after an acid treatment.

Bleaching of Crude Beeswax

So little is known about the methods for removing the adsorbed colors, thus restoring beeswax to its original wax-scale white, that as a rule bleaching may well be left to specialists. However, because of a wide interest in the subject, a brief outline of bleaching methods is given.

There are three types of procedure -- adsorption, sun bleaching, and chemical bleaching. In the first process crude beeswax in the liquid state is mixed with a finely divided adsorbing solid such as Filtrol, fuller's earth, or charcoal. The adsorbent is added to the molten wax, which is then agitated continuously for several hours. The amount of adsorbing agent used depends largely upon the amount of colored material in the wax. After being processed as described above, the liquid wax is forced through a filter press for the removal of any solid materials.

Two methods of sun bleaching are in use: (1) The wax may be melted in shallow trays of glass, aluminum, or stainless steel and exposed to the direct rays of the sun (fig. 3). Suspended materials, as well as resins, settle out and may be scraped off the bottom of the cakes after cooling. (2) The crude wax may be prepared in thin shavings and then exposed to the sun in open-air trays. Bleaching of the flakes is more rapid in the presence of water. In this procedure the wax does not melt but is decolorized in the strip form.

By the chemical procedure color may be partly or entirely removed by agitating the molten wax with chemical reagents that destroy the colored substances. Among the substances used for this purpose are benzil peroxide, dichromic acid, permanganic acid, and salts of hypochlorous acid. These chemical methods must be applied by a technically trained worker.

The method to be followed depends somewhat on the wax, because not all waxes can be bleached by any one of the processes.

Wax-Processing Equipment

Unfortunately, most beeswax-processing equipment on the market is constructed, for economy's sake, from iron. However, since light-yellow or white beeswax often brings as much as 2 cents per pound premium over the black or brown-stained product, the purchase of better rendering equipment is justified. Aluminum and stainless steel, which are both becoming less expensive, should be seriously considered for this purpose. Because of rapid chemical activity, aluminum should not come in direct contact with caustic acid or alkaline solutions.

Much beeswax is badly discolored by the Hershizer press, a fine piece of equipment as commonly manufactured, except that it is constructed of iron. Substitution of a more desirable metal in the construction of a moderate-sized hot-water press should result in better beeswax.

Equipment for acid treatment of waxes can be made from pyrex glass, stainless steel, or monel metal. Ordinary iron vessels (tin-coated or galvanized), wash boilers, and the like are readily attacked by sulfuric acid and are therefore unsatisfactory.

Uses of Beeswax

Beeswax has a wide variety of uses. Some idea of the demand for this product may be gained from production and importation statistics, which give the domestic production as between 3 and 4 million pounds annually and the quantity imported as around 4 million pounds. The beekeeping trade consumes the largest quantity for making comb foundation and queen cells. Perhaps the next two largest outlets are for candles and polishes. The following products and industries use sizable amounts of beeswax (7).

- Binder for composition
- Bricks for buffing
- Candles
- Carbon paper
- Comb foundation
- Composition wax
- Confectionery
- Cosmetics
- Cutlery manufacturing
- Dental wax
- Electrical industries
- Encaustic painting
- Etching
- Floor polish
- Glassware manufacturing
- Grafting wax
- Lithographic ink
- Laundries
- Leather cement
- Lithographic crayons
- Mastic varnish
- Metal composition polish
- Modeling
- Naval stores
- Pattern making
- Pharmaceutical preparations (such as ointments and cerates)
- Phonograph records
- Process engraving and lithographing
- Sail making
- Sealing wax
- Shoe polish
- Tailoring
- Textiles
- Waterproofing
- Winter-sports equipment

Beeswax is especially suited to the making of high-grade candles. As compared with other waxes it has a fairly high melting point (143°-147° F.), and it is rigid enough to stand up well even in hot climates. For liturgical purposes beeswax is definitely preferred, as it burns slowly with a steady bright flame. Paraffin, being much cheaper, is used extensively in the ordinary quality candles.

White beeswax may be artifically colored to any desired tint by adding an oil-soluble dye to the liquid wax. A little practice will be found necessary in manipulating the colors.

Numerous formulas for preparing beeswax for use in grafting wax, floor and leather polishes, and the like will be found in formula books, bee books, and bee journals. The best polishes and cold creams are made by carefully guarded recipes.

Candle Making

The process of molding candles requires particular attention to wax cleaning and careful control of temperature. Most crude wax carries foreign material in a fine state of division, often too fine to be plainly visible to the naked eye. Candles made from such wax do not burn well because these particles float into the wick as the wax is consumed and gradually clog the wick.

Beeswax is very adhesive, sticking firmly to a surface on which it has been heated to a high temperature. Wax melted directly over a flame quickly reaches a temperature far above that of boiling water. The use of a double boiler for melting prevents overheating. Wax that is cooled to 160° or 150° F. after being melted and then poured into cold containers shows little tendency to stick to the container.

Numerous suggestions have been made for keeping beeswax from sticking to molds, such as coating the inside surface of the mold with water, soap solution, starch solution, oil, vaseline, etc. Certain metals adhere to beeswax less than others; for example, aluminum apparently adheres much less than iron. A special mold-metal alloy is used in commercial molding machines. Containers with sloping sides are preferable (fig. 4).

Beeswax shrinks appreciably upon solidifying. Very slow cooling enables the wax to shrink uniformly, resulting in cleavage from the container walls. On the other hand, wax cooled rapidly becomes solid on the outside while remaining liquid in the middle, causing the mass to crack.

One practical method of cooling slowly is to cover the mold with a heavy woolen blanket immediately after it is filled with liquid wax at 150° to 160° F. A well-insulated cabinet for storing the molds is also very convenient. In any case the candles should be left undisturbed for many hours until cold. Chilling below room temperature aids shrinkage.

In commercial candle-molding plants slow cooling is attained by circulating large volumes of warm water around the candle tubes. With such elaborate equipment for temperature control, the candles, which are mostly of paraffin, practically drop out of the mold tubes. Paraffin wax, being rather oily, is much less adhesive than beeswax.

Wax that is sufficiently clean for candles has a sparkling clear appearance, irrespective of color, when in the liquid state. Wax from a solar extractor is as a rule fairly free from the fine particles so objectionable in candle wax. The selection of solar wax for candle making may therefore be a wise choice for a novice.

The wicking for candles has been extensively studied by candle manufacturers, but little of the information gained is available. The wicks are frequently treated with chemicals, the process being called pickling.

Amateur candle makers should procure wicking from some established manufacturer. One wicking manufacturer prepares a square type expressly for beeswax. The proper size of the wick depends on the diameter of the candle.

The wick is readily threaded with a fine wire doubled back on itself to serve as needle. A knot tied on the end of the wick closes the small end of the mold when the wick is pulled into it. A pin longer than the greatest diameter of the mold will hold the wick in place during the pouring and cooling processes. After the knot has been pulled into place, the pin is thrust through the taut wick across the open end of the mold. The knot is cut off before the candle is removed from the mold.

Candle molds are occasionally found in shops displaying second-hand or antique merchandise. A tinner can readily construct new molds from a pattern or specifications. Molds with tapering walls facilitate removal of the candles (fig. 5). Candles from 8 to 12 inches long look well for most uses.

Candles are also made by the dipping process and by tightly rolling thin sheets of the wax around the wick until the desired diameter is attained.

Bloom on Beeswax

The cause of bloom on beeswax is not well understood, if one may judge from the lack of reference to the subject in the literature. Some individuals claim that the deposit is caused by soap used to prevent sticking of the wax cake. It forms, however, on wax before as well as after rendering, and it reappears after a sample that has once bloomed is remelted or the initial accumulation has been rubbed off. This bloom melts at 102° F., which is more than 40 degrees below the melting point of beeswax. Beekeepers refer to the powdery deposit on the unused combs as mildew or mold, but under a microscope this "mold" presents the same characteristic crystals observed on cakes of stored wax.

Twelve samples of crude waxes were stored to determine the time required for the deposit to form. It was found to range from 3 weeks to 3 months. This aging process is reported to improve beeswax for certain uses and to impair it for others. One candle manufacturer capitalized upon the bloom by offering a rare velvet-finished candle; on the other hand, wax modelers are reported sometimes to varnish their products to prevent this objectionable accumulation.

Cleaning of Clothes Spotted with Wax or Propolis

When clothing becomes spotted with beeswax, the major part should be removed with a blunt scraper such as a dull knife or a finger nail, and the spot should then be rubbed with a clean cloth that has been dipped into spirits of turpentine, gasoline, or xylene. If the spot still remains, the garment may be placed on an ironing board and pressed with a hot iron,

a blotter being laid over the spot. The last trace of wax should disappear with this treatment.

Propolis is wholly soluble in alcohol or ammonia and partly soluble in gasoline or xylene. It can be removed with these solvents by the procedure outlined for removing wax. Propolis stains badly. A stain can be bleached with a dilute solution of sodium hypochlorite. Caution is necessary with this bleaching agent, however, especially if the garment carries a dye. Excess hypochlorite can be neutralized with weak oxalic acid or washed away with a soft wet sponge. Oxalic acid is highly poisonous.

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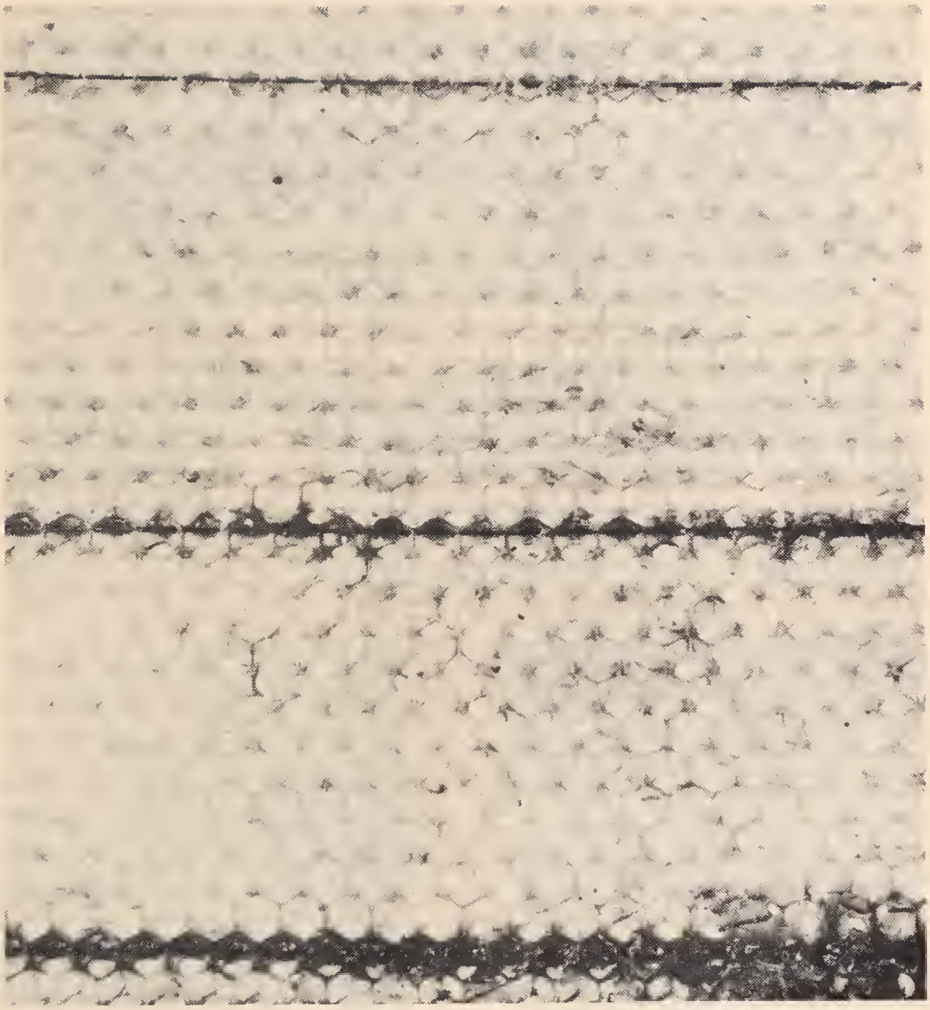

Figure 1.--Browning of wax along the iron frame wires. The cells of a new comb were torn away, thus exposing the original foundation and wire. (Photo by Clifford Clower of the California State Department of Agriculture.)

Figure 2.--Two small solar wax extractors in an apiary at Colusa, Calif. The receptacle at the lower end of each catches the melted beeswax. (From California Agricultural College Extension Circular 100, by J. E. Eckert.)

Figure 3.--Two lots of liquid beeswax being bleached by the sun at a hot spring in Nevada.

Figure 4.—Lower part: Shapes of containers from which beeswax cakes may be readily removed. Upper part: Vessels and wax cakes whose sides are parallel.

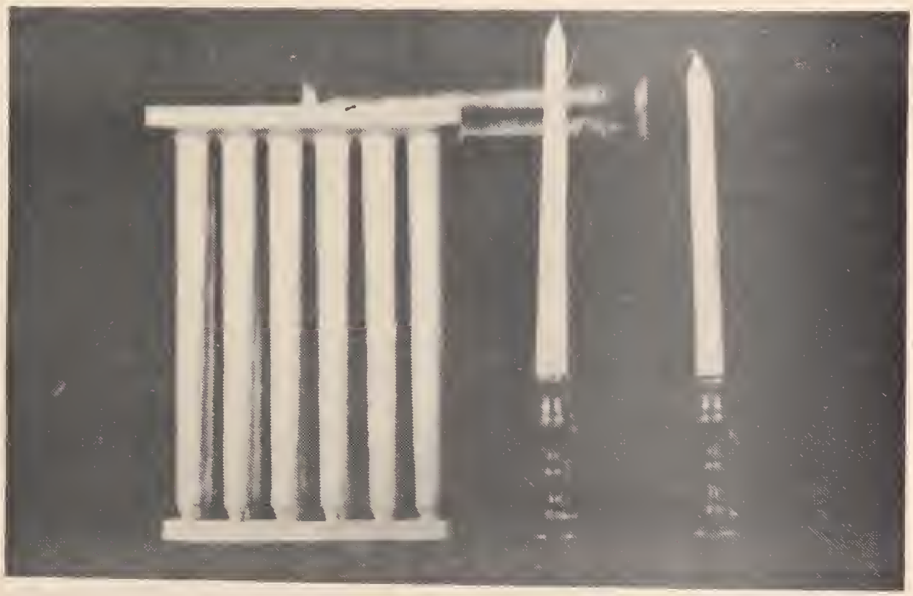

Figure 5.--Beeswax candles and molds.